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Design of A Small Scale Oceanic Wave Energy Converter at Terengganu Coast

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Abstract: Wave energy has the highest energy density of all renewable energy sources and can generate more electrical power since the electrical power demand is increased every year. The main objective of this research is to design a wave energy converter that suitable to use in Malaysia. George E. Dieter design process is used as a framework for all actions, from defining problem to designing the details. Furthermore, SolidWorks software is used to conduct simulation and engineering drawings to analyses the product specification and shows that the model is workable to satisfy the necessity for energy production. The final design of the oceanic wave energy converter is planned to run the generator at 600 rpm to generate about 12kW of electrical power per day. By designing this wave energy converter that suitable for Malaysia wave condition, it will able to generate more electrical energy from ocean and be more effective.

Keywords: Wave Converter, Ocean Energy, Renewable Energy, Sustainable Energy

1. Introduction

Ocean waves are framed as the wind blows over the outside of the sea, making little waves, which inevitably become waves with increasing time and separation. At the point when waves arrive at shallow water, they become temperamental and start to break and can force huge hydrodynamic powers on organisms living in these districts. This energy source is accessible 24 hours daily and the force's capacity thickness multiple times higher than the wind streaming to drive a wind turbine [1]. Ocean wave energy contains the biggest energy density among all sustainable power.

When the technology grows year by year, the demand for electrical energy is also increased. The wave energy converter system must therefore be sized for optimum part-load performance, but it should also be configured with the versatility to absorb all or most of the wave energy available. In addition, most of the devices for wave energy converters are large in size and complex in nature.

The objective of this research is to design and simulate an oceanic wave energy converter that expected the design will fulfil the requirement to supply the energy to household. The devices shall works during days and night to convert the energy from ocean. Project analysis and simulation via SolidWorks Simulation software should be effective at the end of this project. The final results of both

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analysis and simulation should show that the devices are workable and practical for further development.

2. Literature Review

A few thing have been selected to be focused in this literature which are to study in the chosen area where wave energy converter have been practiced and installed, summarize all information that gathered, identify and analysis information in current market. In this research, the literature review are focused on the study of wave energy, wave energy converter and patents

2.1 Wave Energy

Ocean waves are a massive reservoir of energy that is largely untapped, and the capacity for wave energy production is enormous [2]. Ocean surface waves constitute more than 50 percent of the “global ocean energy resource" [3]. Ocean wave power is a more promising resource, because waves originate from storms far out to sea and can travel long distances without significant energy loss, power produced from them is much steadier and more predictable, both day to day [4]. Spectrum of the ocean energy can be seen as in Figure 2.

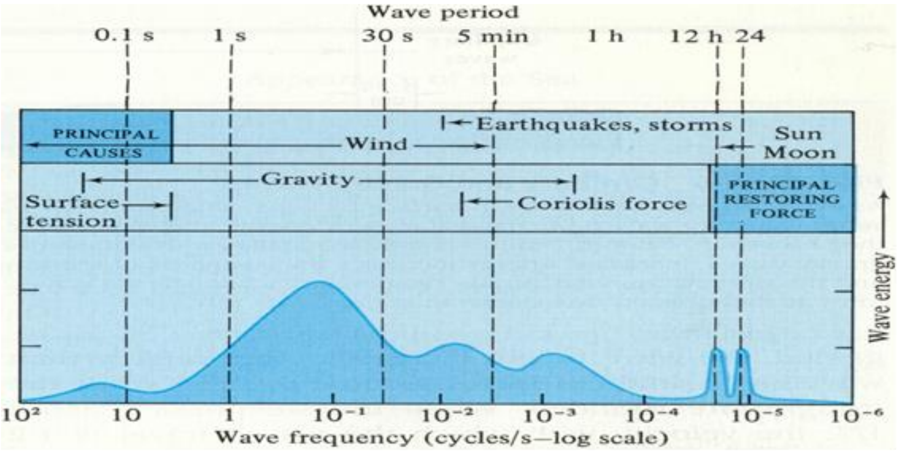

Figure 1: Spectrum of the ocean energy

2.2 Wave Energy Converter

Wave energy converters are instruments that transform to usable mechanical or electrical energy the kinetic and potential energy associated with a traveling wave. People always assume that wave energy converters are a potential source of renewable energy for powering the grid, but there are actually several more wave energy converter applications that are currently in use.

At present, businesses and university study organizations around the world are exploring a variety of various wave energy principles. Although several working models have been built and evaluated through modelling and wave tank testing, only a few designs have advanced to sea testing. However, rapidly dropping costs could cause wave power plants to compete favourably with traditional power plants in the near future.

Naturally, the wide spectrum of wave energy converter models has prompted individuals to consider grouping them in groups. They are generally categorized according to how they operate or the theory of operation, where they work or by their current states of growth. Wave energy converter's operating standards can be defined in different ways and types such as Attenuator, Point Absorber, Submerged Pressure Differential, Oscillating Wave surge, Oscillating Water Column and Overtopping [5].

2.3 Patent Search

A patent is an inventor's legal right to prevent others from manufacturing or utilising his or her creation (Hall, 2007). To assess the possibility, several patents are evaluated and compared. Table 1 displays the patents that have been chosen to be reviewed.

Table 1: Selected Patents

Item	Patent Name	Patent Number
1	Wave attenuator	US2015/0361628A1
2	Wave energy converter	US7909536B2
3	Wave energy converter utilizing pressure differences	US6933623B2
4	System for converting tidal wave energy into electric energy	US8319366B2
5	Oscillating water column wave energy converter incorporated into caisson breakwater	US2005/0207844A1
6	Wave catcher	US2012/0032444A1

3. Project Flow Chart

As shown in Figure 2, George E. Dieter Design Process is used as a framework throughout the project.

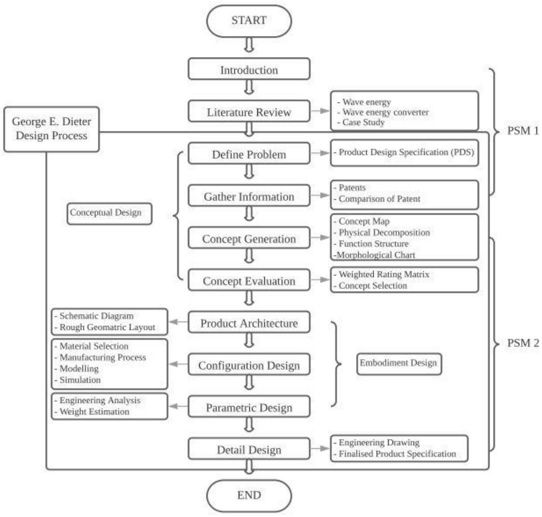

Figure 2: George E. Dieter design process

Before progressing to George E. Dieter's design method, students will begin with the project's introduction, as seen in Figure 2. The introduction of wave energy, the issue statement relating to electricity demand, the background study, and the aim, scope, and significance of the study were discussed at this stage, as shown in Chapter 1. The following chapter, Chapter 2, was used to perform the literature review. Different types of patents linked to the subject were evaluated and analyzed using a scale rating technique to choose the most appropriate and practical patent and product that can benefit humans, the environment, and the ecosystem. After finishing the introduction and literature review, students can continue on to the major body of the design process, which is divided into three phases: conceptual design, embodiment design, and detail design. Every phase had many stages and activities that needed to be discussed in the next sub-topic.

3.1 Product Design Specification

The product design specification is generated as the lead to the completion for the design. Product design specification provided a way or target to be followed by designer clearly. Table 2 shows the PDS of the product.

Table 2: Product Design Specification (PDS)

INTRODUCTION/ REQUIREMENTS	
Title	Oceanic Wave Energy Converter
Design Problem	To design a device that can create a bigger output from a small movement of the device.
Intended Purpose	The device can operate successfully
Special Features	A device that can read the amplitude of the waves for a certain time
Functional Performance	To generate electricity around 10kW a day
Operating Environment	Nearshore environment which having a water depth of between 10 and 20 m
Economic	Low maintenance cost for nearshore compared to offshore
	Longer lifespan with more than 20 years
Geometric Limitation	Total weight should be less than 1000kg
Maintenance, Repair,	No major repair is required
Retirement	Standard parts and components are used
Safety	The device is stable and without any failure occurs within its economic life
	Covering body are added so the mechanism are not directly exposed
	Elimination of hazardous fluids and components
Pollution	Not used any hazardous fluid
Ergonomics	No need man power to run this device
	Simple operation steps
	Easy to do a maintenance

3.2 Full Assembly of the Device

During the design process, it's critical to break down the complex design challenge into manageable chunks and carry out the needed function. After the conceptual design presented in Figure 3, the best product architecture is chosen to build the best system with the success function.

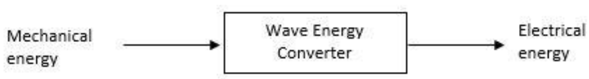

Figure 3: Function Structure

A morphological chart was created to investigate different component designs. Different combinations were assessed in order to determine the design with the greatest rating among three alternative conceptions. Figure 4 displays the concept design with the highest weighted rating.

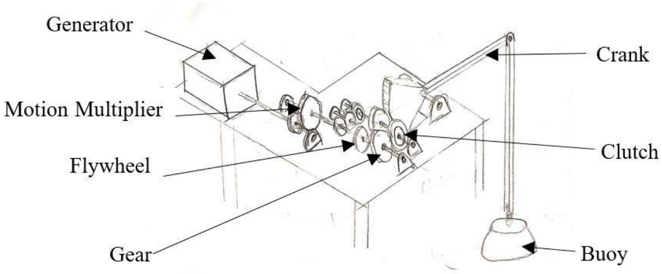

Figure 4: Project sketch

Afterward, SolidWorks is used to build the design for the combination alternative concept. The three-dimensional overview of the wave energy converter device is shown in Figure 5.

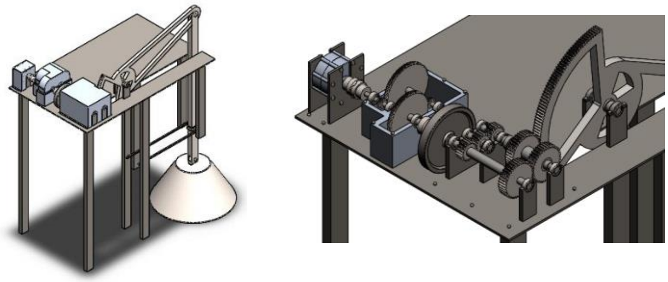

Figure 5: Isometric view

The wave energy converter device's movement and motion are simulated in SolidWorks software. Figure 6 depicts how the buoy was pushed by the velocity of the wave and how the system worked. The overall machine is made up of three sub-assemblies: two power transmission systems and a crank mechanism.

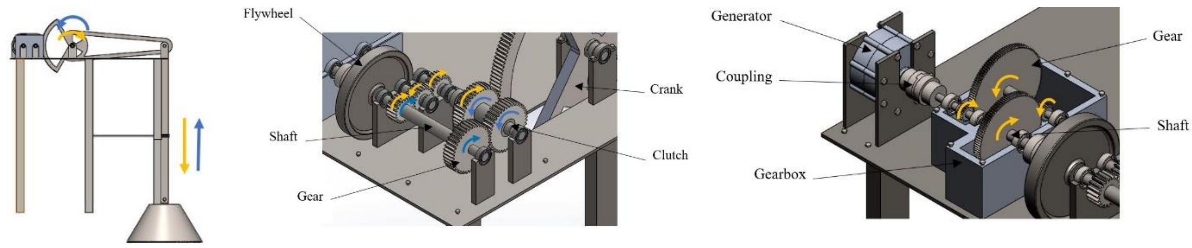

Figure 6: Working system of wave energy converter

3.3 Engineering Analysis

Engineering analysis has been used for decades to validate some principles in the real prototype of the system under design. To verify that the equipment performs properly and has the necessary functionality.

3.3.1 Motion Analysis

Motion analysis in SolidWorks is used to determine the rotation speed of the crank since the wave height is 1.2 m and the duration to complete a period is 8 s. So, the input detail is enter as in Figure 7 and Figure 8 shows the result of the rotation speed of the crank.

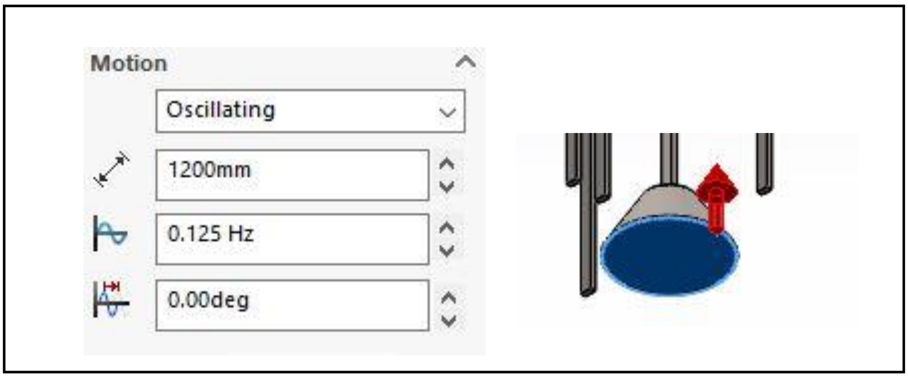

Figure 7: Input detail and location of load

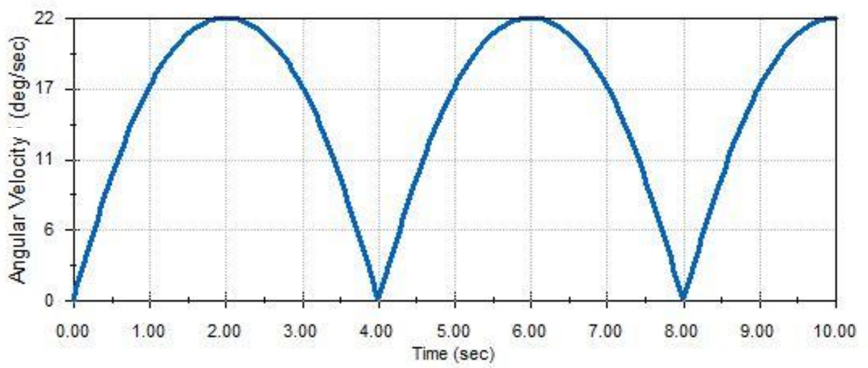

Figure 8: Graph of angular velocity of the crank

Based on Figure 8, the maximum angular velocity of the crank is 22 deg/s.

$$Angular\ velocity, \omega = 22\frac{deg}{s}$$
$$Angular\ velocity, \omega = 22\frac{deg}{s} x \frac{\pi}{180}$$
$$Angular\ velocity, \omega = 0.384\ rad/s$$

Thus,

$$Rotation\ speed, n = \frac{60\omega}{2\pi} \quad \text{Eq. 1}$$
$$Rotaiton\ Speed, n = \frac{60\ x\ 0.384}{2\pi}$$
$$Rotaiton\ Speed, n = 3.67\ rpm$$

So, the rotation speed of the crank is 3.67 rpm.

3.3.2 Gear Ratio

The generator selected is able to generate 500 W per hour with the rotation speed of 600 rpm. Table 3 shows the specification of the 500 W generator.

Table 3: Specification of 500W generator

Model	NE-500M2
Rated Power (W)	500W
Max Power (W)	536W
Rated Voltage (V)	12/24/48V
Rated Rotated Speed (rpm)	600rpm
Top Net Weight (kg)	6.1kg
Output Current	AC
Generator	3 phase permanent magnet synchronous generator
Insulation Class	F
Service Life	More than 20 years
Permanent Magnet Material	Rare Earth Grease
Protection Grade	IP54
Lubrication	Lubrication Grease
Working Temperature	-40˚C - 80˚C

Gear ratio is used to measure a wide variety of mechanical items or other equipment. In this project, main function of gear ratio is to increase the speed and reduce the torque from the crank to generator.

$$Gear\ Ratio = \frac{output\ speed}{input\ speed} \quad \text{Eq. 2}$$

$$Gear\ Ratio = \frac{600}{3.67}$$

$$Gear\ Ratio = 163.5$$

$$Gear\ Ratio = 1{:}\,163.5$$

3.3.3 Rotation Speed

Since the total gear ratio is 1:163.5, three gear sets are applied with three different ratio for each sets which are 1:5, 1:5.45 and 1:6 respectively as shown in the Table 4.

Table 4: Gear ratio for each sets

Gear Sets	Gear	Number of Teeth	Gear Ratio
1st set	Gear 1 Pinion 1	200 40	1:5
2nd set	Gear 2 Pinion 2	109 20	1:5.45
3rd set	Gear 3 Pinion 3	120 20	1:6

Figure 9 shows the result of the rotation speed of shaft that connected to the generator.

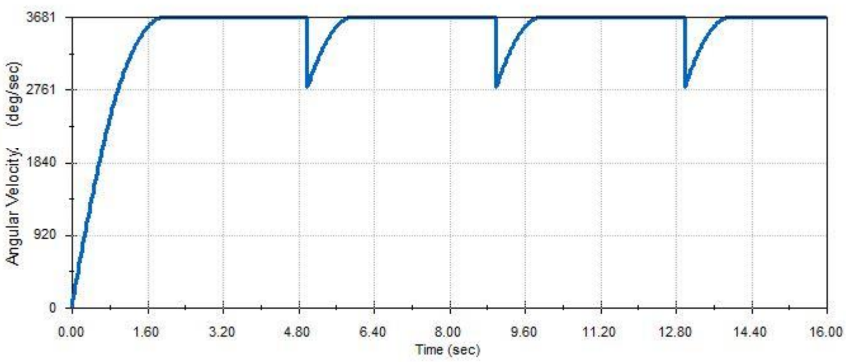

Figure 9: Speed of output shaft

From Figure 9, the maximum rotation speed of output shaft is 3681 deg/s. Because the rotation speed is measured in deg/s, the formula below illustrates the conversion from deg/s to rpm.

$$Angular\ velocity, \omega = 3681 \frac{deg}{s}$$
$$Angular\ velocity, \omega = 3681 \frac{deg}{s} x \frac{\pi}{180}$$
$$Angular\ velocity, \omega = 64.25\ rad/s$$

Thus,

$$Rotation\ speed, n = \frac{60\omega}{2\pi}$$
$$Rotation\ Speed, n = \frac{60\ x\ 64.25}{2\pi}$$
$$Rotation\ Speed, n = 613.5\ rpm$$

As a results, the rotation speed obtain from the wave motion to run the generator is 613.5 rpm.

3.4 Engineering Drawing

SolidWorks is used to show engineering drawings, which include a bill of materials and dimensions. Each mechanism, when combined with the appropriate material, resulted in an exact product specification. Figure 10 depicts the complete assembly for the wave energy converter device's overall design.

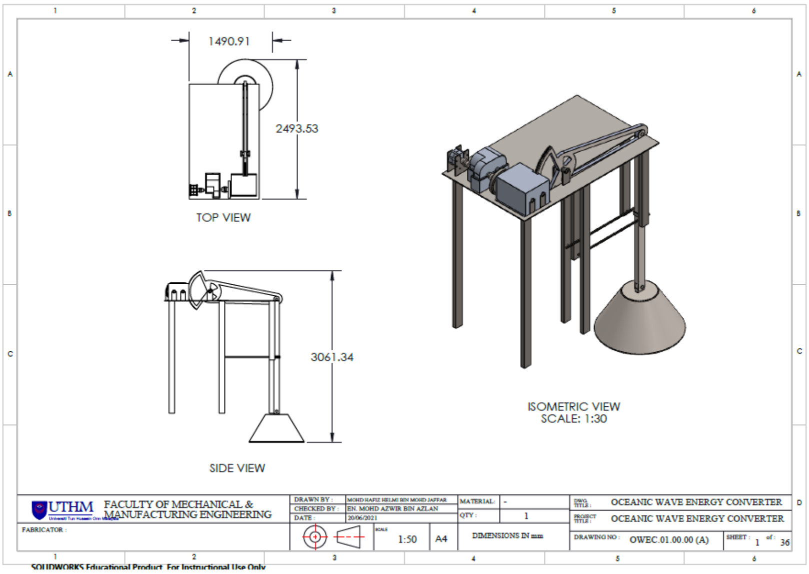

Figure 10: Full assembly drawing

3.5 Product Specification

After completing the design process, the product specification is finished in Table 5 to summarise the key details of the product.

Table 5: Product specification

Product specification	Description
Device weight	1064.98kg
Dimension	2495mm x 1491mm x 3062mm
Generator Power	0.5kW/h
Rotation Speed	613rpm
Daily power	12kW

4. Conclusion

In conclusion, the design method for an Oceanic Wave Energy Converter is based on George E. Dieter's process. The goal of this project is to transform wave energy into electrical energy that may be used in the home. Parts of the device have been developed, simulated, analysed, and drawings have been generated using SolidWorks. The final design of the gadget, which can create 12 kW per day with a generator rotation speed of 600 rpm. This gadget weighs 1064.98 kg and measures 2495mm in length, 1491mm in width, and 3062mm in height. The proposed machine is anticipated to be useful in the home.

Acknowledgement

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